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METHODS OF POSTPARTUM BLOOD LOSS MEASUREMENT IN INDONESIA SHOULD BE MODIFIED FOR BETTER ACCURACY: A LITERATURE REVIEW

**Siska Febrina Fauziah*, Melyana Nurul Widyawati,
Tecky Afifah Santy Amarta**

*Postgraduate Applied Science Program in Midwifery,
Poltekkes Kemenkes Semarang, Semarang, Indonesia,*

Corresponding author's e-mail: siskafebrinafauziah90@gmail.com

ABSTRACT

Backgrounds: Assessment of blood loss after delivery is important because intervention in the “golden hour” is crucial to prevent maternal morbidity and mortality. In fact, the biggest obstacle in overcoming postpartum blood loss are symptom recognition, accuracy, and timely diagnosis.

Aims: The objective of this study was to analyze the strengths and weaknesses between visual estimation and quantification of blood loss measurements.

Methods: Literature review was conducted using the electronic databases Science Direct, Pubmed, and Google Scholar. Measurement of blood loss and postpartum hemorrhage was used as keywords in searching strategy. A total of 23 from 17.200 of publications range from 2010 until May 2017 and presented in English language were included in this review.

Results: Many studies show that quantification of blood loss method is better than visual estimation. Visual estimation of blood loss was imprecise, tend to underestimate blood loss, and thus to delay diagnosis of PPH, whilst quantification of blood loss more accurate and objective. Nonetheless, quantification methods not used routinely due to their unavailability, more time consuming, complicated, costly, and analyst workload increases.

Conclusions: Modified measurement method and its existing protocol needed to overcome blood loss during postpartum.

Keywords : Blood loss, postpartum hemorrhage, measurement

INTRODUCTION

Postpartum hemorrhage (PPH) is the leading direct obstetric cause of maternal mortality worldwide. It occurs in nearly 14 million births and is responsible for approximately 140,000 maternal deaths each year[1]. World Health Organization (WHO) stated that nearly three-fourth of obstetric hemorrhage occurred in postpartum period[2]. This pattern was similar with the condition in Indonesia.

In 2015, maternal mortality rate in Indonesia was 305 per 100,000 live births[3] and 30% of it is caused by obstetric hemorrhage[4]. In the smaller region, Central Java, maternal mortality rate was 109.65 per 100,000 live births and obstetric hemorrhages were responsible for 20.26% maternal deaths in 2016[5]. Ika Fibriana analyzed the causes of maternal mortality in Cilacap, a district in Central Java. It was found that obstetric hemorrhage was the leading direct of maternal mortality and 88.2% of it occurred in postpartum period[6]. Immediate postpartum hemorrhage is defined as excessive blood loss more over or equal with 500 mL after normal delivery[7-9]. Assessment of blood loss after delivery is important because active intervention in the “golden hour” is crucial to prevent maternal morbidity and

mortality[10]. But in fact, the largest barriers in treating postpartum hemorrhage are symptom recognition and accurate, timely diagnosis[11, 12].

There are many ways to estimate the blood loss after delivery. In practice, clinicians can rely on several methods of quantification – subjective (visual estimate) or objective (collector bag, weighing compresses or sanitary pads, or laboratory analysis). However, in Indonesia, there is no standardized protocols for estimating blood loss following a vaginal delivery[8]. Although the ideal measurement of postpartum blood loss involves the use of objective tools, visual estimation is still the most commonly used in dily obstetric practices[12].

The objective of this study was to analyze the measurement of blood loss methods either subjective or objective approach. So that we could choose the best option for measuring the blood loss or get the useful point to modify the method that appropriate in Indonesia.

METHODS

The research articles were reviewed from electronic databases including Science Direct, Pubmed, Google Scholar and any other related websites. The number of keywords were used including **“Measurement of Blood Loss”** and **“Postpartum Hemorrhage”**. A total 23 from 17,200 of publications range from 2010 until May 2017, which were discussed about measurement of blood loss method and presented in English language, were included in this review. In addition, relevant chapters of textbooks and current guidelines were examined to capture any further information or additional reports not identified in the electronic search.

RESULTS

The methods used to measure blood loss are categorized into visual estimation of blood loss and quantification of blood loss. Visual estimation is subjective method that measured the amount of blood loss visually. Meanwhile quantification of blood loss is objective method that measured the amount of blood loss by using certain calculation[11]. There are three types of quantification of blood loss methods: gravimetric, utilization of under-buttocks drapes, and laboratory analysis. In this section, the method will be described based on the result of reviewed previous studies.

Visual Estimation

Half of total publications reviewed in this review discussed about visual estimation of blood loss. Parayre et al[13] and Yoong et al[14] evaluated the accuracy of visual estimation by asking health providers to estimate simulated blood loss visually. Both of the studies showed that visual estimation was inaccurate and tend to overestimate the large volume and underestimate the small volume. Parayre et al[13] suggested that the accuracy of visual estimation was 35.34%.

Lertbunnaphong et al[15] compared visual estimation to utilization of a novel birthing drape. Immediately after delivery, a birth attendant inserted the drape under the patient’s buttocks. Postpartum blood loss was measured by visual estimation and then the blood from the drape was poured into a standard cylinder and measured objectively. Visual estimation was found to be inaccurate, resulting underestimation, with low correspondence and poor agreement compared to objective measurement using the birthing drape. Two-third of immediate PPH cases were misdiagnosed using visual estimation. Al Kadri et al[16] compared visual estimation and gravimetric measurement. There was a significant difference between the gravimetric calculated blood loss and health care providers’ estimation with percentage of error by about 30%. This study suggest the better accuracy of visual estimation from previous study. Golmakini et al[17] confirmed the result of this study.

Withanathantrige et al[18] assessed the agreement between visual estimation, gravimetric method and calculation based on hemoglobin levels. They found that visual estimation had tendency to be underestimated when blood loss ≥ 500 mL and to be overestimated when blood loss < 500 mL compared

to gravimetric method. The visual estimation had also less agreement than gravimetric method compared to calculation based on hemoglobin levels.

Ram et al[19] compared the accuracy of visual estimation with actual blood loss which was calculated based on haematocrit value. When the average of blood loss is small, the accuracy rate of blood loss estimation is high. In contrast, when the average of blood loss exceeds 500 mL, the accuracy decreases significantly. This suggests that clinical estimation is inaccurate as the blood loss increases.

Beside of low accuracy, many studies suggested that the visual estimation of blood loss among various members of medical team could be different[14, 20-23]. This discrepancy may lead to a conflict with treatment decision and delay the treatment that should be given[21]. The right time for giving resuscitation is very important and late recognition of significant blood loss may delay intervention until hemorrhage has occurred[23]. To overcome these problems, many studies tried to modify visual estimation by utilizing visual aid, conducting estimation training, or creating a novel tool that can be used to measure blood loss as follow descriptions.

Zuckerwise et al[23] designed a pocket card containing images of blood on common obstetric materials to serve as visual aid. They also created six stations with known volumes of artificial blood using materials from standard delivery kits and asked participants to estimate blood loss visually across a variety of volumes and materials before and after receiving the visual aid. The result showed that visual estimation was inaccurate and tend to overestimate the small volumes and underestimate the larger volume. However, the visual aid were effective to improve the accuracy of blood volume estimation as much as 34.9%. Clinical background and years of experience did not affect the accuracy of health providers' estimation[14, 16, 20, 22, 23].

Toledo et al[22], Al Kadri et al[20] and Khaldikar et al[21] assessed the impact of educational session on the accuracy of visual estimation. Participants of the studies were asked to estimate the simulated blood loss before and after training. In the pre-test, participants' assessment were inaccurate which tended to overestimate the large volume and underestimate the small volume. However, the accuracy were improved significantly after training. Toledo et al[22] suggested that educational session improved the accuracy of visual estimation by 34%. This indicated the beneficial impact of training on visual assessment. In the other study, Toledo et al[24] conducted the research to evaluate retention of blood loss estimation skills after training. They found that decay in blood loss estimation skills occurred by 9 months after training. So that the training should be given routinely to maintain the skills.

Wilcox et al[25] conducted the trial of special designed underpad. Visual estimation of blood loss was calculated by multiplying the number of blood-saturated squares or partial squares by 50 mL. The visual estimation blood loss then compared with the actual blood loss calculated based on Mat weight before and after use (volume of blood loss). The accuracy of this method was 69% of the time within 100 mL and 97% at the time within 200 mL. Meanwhile the mean discrepancy was 80,91 mL compared to actual blood loss.

Other study lead by Sharareh[26] utilized the sophistication of technology by using Triton tablet system. The amount of blood loss and hemoglobin level could be determined by snapshotting the absorbed blood only. Measures of surgical sponge estimated blood loss from the Triton tablet system were compared to photometric analysis. The result showed a significant positive correlation between Triton tablet system and photometric analysis with respect to intra-operative haemoglobin and blood loss at 0.92 and 0.91, respectively. It is the best accuracy for visual estimation method that had ever studied.

Aside from the inaccuracy which more be discussed in the previous studies, it should be realized that the major advantage of visual estimation is that this method is a real time assessment and enables the birth attendants to correlate findings, on an individualized basis, with the clinical presentation[27]. The accuracy could be improved by utilization of visual aid, routine training and modification of the tool that used to measure the blood loss. This method is also the most frequently practiced method in

obstetric practices[12]. It is because this method is relatively straightforward and requires no expenditure[27]. It should be kept in mind that over 99% of maternal mortalities take place in the low resource settings[28]. The method should not only be accurate, but should also be practical, affordable, and able to be implemented in daily practices.

Quantification of Blood Loss

Gravimetric

The gravimetric method is one of the objective method in calculating postpartum blood loss. It constitutes the weighing of collected blood lost during delivery as well as materials such as soaked pads on a sensitive scale and subtracting the known dry weights of these materials to determine the actual blood loss[27]. The difference in weight provides a rough estimate of blood loss; 1 gram equals 1 mL[11].

Vitello et al[29] conducted validation study of the gravimetric method of measuring intraoperative blood loss. As much as 50 μ L of whole blood was weighed from eighteen rats. A distilled water control was weighed for each blood sample. This study confirmed that the measure density of blood is similar to water. So that, this helps verify the use of gravimetric method to convert 1 gram of blood to 1 mL of blood.

Lilley et al[30] conducted a research to validate the accuracy of gravimetric method to measure the blood loss. For validation exercise, in a simulated PPH scenarios using known volumes of artificial blood, the accuracy of gravimetric measurement was compared with visual estimation made by delivery suit staff. It was confirmed that visual estimation is inaccurate which the mean error was 34,7%. In contrast, using gravimetric method in the same scenarios, the volume could be accurately measured with a mean error of 4%. Meanwhile in the clinical observation study, they found that gravimetric measurement of blood loss is correlated with the fall in hemoglobin.

Atukunda et al[31] compared gravimetric method to a reference standard of hemoglobin decrease of >10% to validate the accuracy of the method. The result showed that gravimetric method generally had a poor sensitivity (<75%) for detection PPH. Although this method will possible to miss few cases of PPH because of its poor sensitivity, the specificity and the positive predictive value (PPV) which were > 90% make it a reasonable option as a means of identifying PPH in certain settings where laboratory test is unavailable.

The gravimetric method requires no more resources than a baby weighing scale and basic mathematical ability, and could be thought routinely and used in all maternity services[30]. A variety of scales from elaborate ones that hang to small, household, digital scale that measure in grams can be placed in each labor and operating room[32, 33]. However, quantifying the blood loss using gravimetric method is realized substantially increases the workload of clinicians because it is complicated and time-consuming to use, especially in a busy clinical setting[15]. Inaccuracies can arise at several steps in this procedure, especially when collecting the blood[27].

Utilization of Under-buttocks Drape

Under-buttock drape is used to collect the blood loss after delivery[11]. There are two ways to measure the blood loss by using the drape. The first, the blood is collected into the drape or collector bag then poured into calibrated container or weighted with the soaked gauze or underpad[11, 15, 34]. Meanwhile in the second way, the blood loss was measured directly by using calibrated drape[35, 36].

Brooks et al[34] conducted a prospective simulated study by asking participants to measure the blood loss by using under-buttocks drape and baby scale. Following the first test, they recieved visual aid as additional tool to measure the blood loss by using under-buttocks drape. The estimation of blood loss from both of the tests were compared to the actual blood loss that known by researchers. The use of visual aid in addition to a collector bag did not improve the health providers' estimation and resulted more frequent overestimation when estimating the blood loss.

Different to previous study, Legendre et al[35] conducted simulation training by creating six different scenarios of vaginal delivery. The participants were asked to estimate the blood loss by using calibrated drape. The accuracy of estimated blood loss using the calibrated drape was more than 96%. Tixier et al[36] conducted a prospective cohort study of 122 patients. The measurement of blood loss using calibrated drape compared to decreased level of hemoglobin and hematocrit. By using the calibrated drape, clinicians could estimate the blood loss directly without the need to weigh or pour the blood into other graduated container to measure the blood loss. For a threshold of 300 mL, calibrated drape had high sensitivity and specificity which were 88.9% and 82.7%, respectively.

By utilizing underbuttocks-drape, especially when using the second way measurement as described above, it is only required the calibrated drape to measure the blood loss. This drape should be inserted under the buttocks of the mother immediately after delivery and the blood loss could be measured directly. The error in estimating blood loss can arise from failure to avoid contaminated blood with amniotic fluid or note all the blood in the stained linen[12]. The cost of this drape was 0.86 €[36].

Laboratory Analysis

Several studies used laboratory analysis as the golden standard to evaluate the accuracy of measurement of blood loss. By using this method, of course it is needed the blood samples that were taken before and after the birth. Based on hemoglobin and/or hematocrit level, PPH was diagnosed when the delta for the hemoglobin was > 3 g/dL and/or when the delta for hematocrit was > 10 points which the blood samples were taken after admission and 2 – 3 days after the birth[16, 30, 36]. Meanwhile Atukunda et al adapted reference that could be adapted is the incidence of more than 10% decrease in hemoglobin level from blood samples that were taken immediately after admission and 24 hours after the birth[31]. Beside of hemoglobin and hematocrit level, other studies suggest that fibrinogen level was useful early biomarker for predicting pregression of PPH [37-39]. Cortet et al[37] compared fibrinogen levels in patients whose PPH worsened and became severe and those whose PPH remained non-severe. The result showed that fibrinogen level was associated with PPH severity independently of other laboratory factors. When the fibrinogen level was < 2 g/L, the risk of severe PPH increased 12 times. A fibrinogen level between 2 and 3 g/L, usually considered normal, is also associated with a nearly doubled risk of severe PPH. Collins et al[38] confirmed the result of this study and they also found that Fitem as effective as fibrinogen could be made as biomarker for progression of PPH.

De Lloyd et al[39] showed the similar finding about the utility of fibrinogen level for predicting PPH. They also found that the fibrinogen level fell progressively as the estimated blood loss increase. Nonetheless, the fall of hemoglobin level was still useable as good predictor of PPH when the blood loss was < 3000 mL.

Laboratory analysis is the most accurate method for measuring the blood loss after delivery because this method is able to monitor the biomarker that can represent the amount of blood loss[12]. So that, whole blood check, including hemoglobin, hematocrit, fibrinogen and fitem, as routine intervention will be advantageous in postpartum hemorrhage management[37-39]. Unfortunately, laboratory analysis is impractical because this method should be practiced by expertise and need special equipments to give the best result[33]. This method is also time consuming because the result of laboratory analysis can be achieved at least after 24 hours or after 2-3 days postpartum to distinguish the physiological changes and blood loss confirmation[12, 33]. It means when the patient confirmed has bled or is bleeding, the intervention will be too late to do if the diagnosis is only rely on this method.

DISCUSSION

In this section, the methods were compared to be analyzed the strengths and weaknesses of each method based on its accuracy, simplicity and availability. The method was accurate when the error rate was less than 20% because it is just 20% for overestimation or underestimation was considered to be the maximum individual difference that could be tolerated without interfering with patient

management[40]. Meanwhile the simplicity and availability of the method defined by authors as ease to practice by midwives and required tool for measurements was available in Indonesia.

Based on the result of previous studies that reviewed in this review, the most accurate method was laboratory analysis which commonly used as gold standard for other measurements[12, 18, 19, 30, 31, 36]; followed by utilization of calibrated drape with 88.9% and 82.7% for the sensitivity and specificity, respectively[36]; then gravimetric method which had poor sensitivity but had high specificity and positive predictive value (>90%)[31], and the least accurate was visual estimation (33.3% – 70%)[13, 15-17].

The inaccuracy of each method has the chance to arise[12, 27]. However, visual estimation training and the use of visual aid had been proved can improve health care provider's accuracy in estimating blood loss and decrease the error although it will not eliminate it and still remains overestimation or underestimation[20-23]. When visual aids or visual estimation training were offered, the accuracy of visual estimation improve significantly by 34% and 34.9% for utilization of visual aid and visual estimation training, respectively[22, 23]. It seems that visual estimation of blood loss can be used in labour and delivery suits if appropriate training and education are implemented[20-22].

Based on the simplicity of the method, the most simple method is visual estimation followed by utilization of calibrated drape, gravimetric method, and laboratory analysis. The visual estimation could provide real-time assessment and required no expenditure because the assessment is only depend on the eyesight[27]. The same as visual estimation, the utilization of calibrated drape, could also provide a real-time assessment but it certainly need that sepecial tool to measure the blood loss and clinicians could be careful when collected the blood[35, 36].

Beside needs special equipments, gravimetric method and laboratory analysis were relatively time-consuming because of the procedure[12]. By using gravimetric method, clinicians should weigh all of materials that used to absorbe the blood before and after the birth. The blood loss was known by subtracting the wet weight of materials with the dry weight[11, 16, 27]. Meanwhile laboratory analysis off course ideally should perform in laboratory by expertise to examine the blood sample which were taken before and after the birth. There was also standard time for taking the blood sample after birth to avoid the bias from physiological changes at least 24 hours[16, 31, 36].

The last is about the availability of required tool to measure the blood loss. As mentioned earlier, visual estimation does not require any other tools beside midwife's eyesight[27]. So that visual estimation can be performed anywhere and anytime. Gravimetric method needs digital baby weigh scale that can be placed in each labor room[16, 17, 31-33]. The cost of digital baby scale was vary but it is relatively not expensive for reusable tool. In contrast, the cost of calibrated drape was 0.86 €[36] or equal to IDR 13,523.5 which three times more expensive than commonly used underpad for disposable use. It has also not available yet in Indonesia. It needs high cost to provide laboratory analysis as method to measure the blood loss because the needs of special equipments which relatively expensive and the needs of expertise to do this method properly[12]. The examination also needs blood sample before and after birth which automatically doubled the price.

Based on the description above and realizing that Indonesia is one of developing countries, visual estimation is still the the most appropriate method for measuring the blood loss after delivery in Indonesia. Although many studies suggested that visual estimation was not recommended anymore[12, 14, 15, 30], we believe that midwives still have to retain this skill, moreover the objective method application in developing countries still have to be strived. But certainly, it needs to be modified to give the better accuracy.

Wilcox et al[25], Sharareh et al[26], Tixier et al[36] and Legendre et al[35] modified visual estimation by combining visual estimation principle and quantification method principle. The blood loss could be assessed directly and visually according to standard measurement as the reference to do the estimation,

and it resulted the better accuracy. The strength of visual estimation provide a real-time assessment and the strength of quantification method improve the accuracy of the modified method. It indicates that by combining the principle of the methods, the two methods will reduce the weaknesses and increase the strengths each other. So that it resulted the better performance.

The study that lead by Zuckerwise et al[23] showed that visual aid could improve the estimation by 34.9% because the participants of the study estimate the blood loss from the same materials provided. In Indonesia, the utilization of visual aid had been used in daily practices. For example, the midwives estimated the blood loss by interpreting that full soaked of sanitary pad as 100 mL, half soaked of sanitary pad as 50 mL, half filled of kidney dish as 250 mL, completely full of kidney dish as 500 mL, half soaked of sarong as 400 mL, and fully soaked sarong as 700 mL[10].

Contrary to the research setting, it should be realized that there are various sanitary pads and sarongs which could have different capacity[27]. The perception of half soaked could also different for one to the others because the absorbed blood on the sanitary pad or sarong had irregular shape[21]. So, for getting the same benefit as this study, those materials that were used in visual aid should be materials that were used in real clinical settings. It is very possible that every labor rooms have their own visual aid according to materials that they used. Beside the size of materials and the capacity of absorbed blood, visual aid should also inform about the absorptive capacity of the materials which had been measured.

To minimize the overestimation or underestimation, by adapting Wilcox's study[25], it could be drawn the line scale on the visual aid surface, so that it had several squares. The estimated volume of each square should be tested in order this calibrated visual aid could be used as the reference standard measurement when estimating the blood loss. This modification should be strengthen by routine visual estimation training to improve the estimation and maintain the skills[20-22, 24]. As the Toledo's study[22], the model of the training could be applied as live or web-based training without reduce the effectivity. By this way, it is expected that the percentage of error of visual estimation would not be more than 20% .

Beside of the method, the other important thing to reach the successful of postpartum hemorrhage management is the needs of health policy formed as protocol or guideliness comprehensively[33, 41, 42]. But in fact, in Indonesia, there is no standardized protocol for estimating blood loss following a vaginal delivery[8]. Efforts should be made to unify the assessment and management of PPH patients through education and standardization as mentioned earlier. The policy should not concern about the clinical procedure only but also have to regulate the availability of required tools to measure the blood loss.

CONCLUSIONS

Blood loss during childbirth has been and continues to be a significant issue. Methods to accurately determine blood loss that are simple and costless are desperately needed. Visual estimation is still the most appropriate method for measuring the blood loss after delivery in Indonesia. The weakness of visual estimation is only about its accuracy that could be improved in various ways. Modifying the visual estimation by making the principle of quantification methods as integrated part of this method would provide a real-time assessment and improve the accuracy. The use of materials with known absorptive capacity that performed together with calibrated visual aid and supported by routine visual estimation training and it's existing protocol will result the better accuracy in diagnosing postpartum blood loss in Indonesia. This modification suggested that visual estimation still proper to be used especially in low resource settings.

CONFLICT OF INTEREST

There is no conflict of interest.

REFERENCES

- [1] World Health Organization. Maternal, newborn, child and adolescent health 2014. Available from: http://www.who.int/maternal_child_adolescent/topics/maternal_perinatal/en/.
- [2] Say L, Chou D, Gemmill A, Tunçalp Ö, Moller A-B, Daniels J, et al. Global causes of maternal death: a WHO systematic analysis. *The Lancet Global Health*. 2014;2(6):e323-e33.
- [3] Kementerian Kesehatan RI. Profil Kesehatan Indonesia Tahun 2015. Jakarta: Kementerian Kesehatan RI; 2016.
- [4] Trihono. Hasil Capaian Awal: Evidence Summit on Reducing Maternal and Neonatal Mortality in Indonesia 2016-2017. Jakarta: Akademi Ilmu Pengetahuan Indonesia; 2016.
- [5] Dinas Kesehatan Provinsi Jawa Tengah. Buku Saku Kesehatan Tahun 2016. Semarang: Dinas Kesehatan Provinsi Jawa Tengah; 2016. p. 25-6.
- [6] Ika Fibriana A. Faktor-faktor risiko yang mempengaruhi kematian maternal (Studi kasus di Kabupaten Cilacap). *Jurnal Epidemiologi*. 2007.
- [7] American Congress of Obstetricians and Gynecologists. Obstetric Hemorrhage 2016. Available from: <http://www.acog.org/About-ACOG/ACOG-Districts/District-II/SMI-OB-Hemorrhage>.
- [8] Himpunan Kedokteran Feto Maternal. Pedoman Nasional Pelayanan Kedokteran: Perdarahan Pasca-Salin. Jakarta: Perkumpulan Obstetri dan Ginekologi Indonesia; 2016.
- [9] World Health Organization. WHO recommendations for the prevention and treatment of postpartum haemorrhage: World Health Organization; 2012.
- [10] Ganeshan M, Suharjo H. Management of Post Partum Haemorrhage. In: O&G Do, editor. Sarawak: Sarawak General Hospital; 2012.
- [11] AWHONN. Quantification of Blood Loss: AWHONN Practice Brief Number 1. *Journal of Obstetric, Gynecologic, & Neonatal Nursing*. 2015;44(1):158-60.
- [12] Schorn MN. Measurement of blood loss: review of the literature. *Journal of midwifery & women's health*. 2010;55(1):20-7.
- [13] Parayre I, Rivière O, Debost-Légrand A, Lémery D, Vendittelli F. Reliability of student midwives' visual estimate of blood loss in the immediate postpartum period: A cross-sectional study. *International journal of nursing studies*. 2015;52(12):1798-803.
- [14] Yoong W, Karavolos S, Damodaram M, Madgwick K, Milestone N, Al-Habib A, et al. Observer accuracy and reproducibility of visual estimation of blood loss in obstetrics: how accurate and consistent are health-care professionals? *Archives of gynecology and obstetrics*. 2010;281(2):207.
- [15] Lertbunnaphong T, Lapthanapat N, Leetheeragul J, Hakularb P, Ownon A. Postpartum blood loss: visual estimation versus objective quantification with a novel birthing drape. *Singapore Medical Journal*. 2016;57(6):325.
- [16] Al Kadri HM, Al Anazi BK, Tamim HM. Visual estimation versus gravimetric measurement of postpartum blood loss: a prospective cohort study. *Archives of gynecology and obstetrics*. 2011;283(6):1207-13.
- [17] Golmakani N, Khaleghinezhad K, Dadgar S, Hashempour M, Baharian N. Comparing the estimation of postpartum hemorrhage using the weighting method and National Guideline with the postpartum hemorrhage estimation by midwives. *Iranian Journal of Nursing and Midwifery Research*. 2015;20(4):471-5.
- [18] Withanathantrige M, Goonewardene M, Dandeniya R, Gunatilake P, Gamage S. Comparison of four methods of blood loss estimation after cesarean delivery. *International Journal of Gynecology & Obstetrics*. 2016;135(1):51-5.
- [19] Ram GG, Suresh P, Vijayaraghavan PV. Surgeons often underestimate the amount of blood loss in replacement surgeries. *Chinese Journal of Traumatology*. 2014;17(4):225-8.
- [20] Al-Kadri HM, Dahlawi H, Al Airan M, Elsherif E, Tawfeeq N, Mokhele Y, et al. Effect of education and clinical assessment on the accuracy of post partum blood loss estimation. *BMC pregnancy and childbirth*. 2014;14(1):110.
- [21] Khadilkar SS, Sood A, Ahire P. Quantification of Peri-partum Blood Loss: Training Module and Clot Conversion Factor. *The Journal of Obstetrics and Gynecology of India*. 2016;66(1):307-14.
- [22] Toledo P, McCarthy RJ, Burke CA, Goetz K, Wong CA, Grobman WA. The effect of live and web-based education on the accuracy of blood-loss estimation in simulated obstetric scenarios. *American journal of obstetrics and gynecology*. 2010;202(4):400. e1-. e5.
- [23] Zuckerwise LC, Pettker CM, Illuzzi J, Raab CR, Lipkind HS. Use of a novel visual aid to improve estimation of obstetric blood loss. *Obstetrics & Gynecology*. 2014;123(5):982-6.
- [24] Toledo P, Eosakul ST, Goetz K, Wong CA, Grobman WA. Decay in blood loss estimation skills after web-based didactic training. *Simulation in Healthcare*. 2012;7(1):18-21.
- [25] Wilcox L, Ramprasad C, Gutierrez A, Oden M, Richards-Kortum R, Sangi-Haghighi H, et al. Diagnosing Postpartum Hemorrhage: A New Way to Assess Blood Loss in a Low-Resource Setting. *Maternal and Child Health Journal*. 2016;1-8.
- [26] Sharareh B, Spencer Woolwine SS, Abraham P, Schwarzkopf R. Real time intraoperative monitoring of blood loss with a novel tablet application. *The open orthopaedics journal*. 2015;9:422.
- [27] PATH. Blood Loss Measurement USA: PATH; 2013. Available from: <https://sites.path.org/mnhitech/assessment/postpartum-hemorrhage/blood-loss-measurement/>.
- [28] World Health Organization. Maternal Mortality 2016. Available from: <http://www.who.int/mediacentre/factsheets/fs348/en/>.

- [29] Vitello DJ, Ripper RM, Fettiplace MR, Weinberg GL, Vitello JM. Blood density is nearly equal to water density: a validation study of the gravimetric method of measuring intraoperative blood loss. *Journal of veterinary medicine*. 2015;2015.
- [30] Lilley G, Burkett-St-Laurent D, Precious E, Bruynseels D, Kaye A, Sanders J, et al. Measurement of blood loss during postpartum haemorrhage. *International journal of obstetric anesthesia*. 2015;24(1):8-14.
- [31] Atukunda EC, Mugenyi GR, Obua C, Atuhumuza EB, Musinguzi N, Tornes YF, et al. Measuring Post-Partum Haemorrhage in Low-Resource Settings: The Diagnostic Validity of Weighed Blood Loss versus Quantitative Changes in Hemoglobin. *PloS one*. 2016;11(4):e0152408.
- [32] Dillard AC. Obstetric Hemorrhage in the Rural Emergency Department: Rapid Response. *Journal of Emergency Nursing*. 2017;43(1):15-20.
- [33] Gabel KT, Weeber TA. Measuring and communicating blood loss during obstetric hemorrhage. *Journal of Obstetric, Gynecologic, & Neonatal Nursing*. 2012;41(4):551-8.
- [34] Brooks M, Legendre G, Brun S, Bouet PE, Mendes LP, Merlot B, et al. Use of a Visual Aid in addition to a Collector Bag to Evaluate Postpartum Blood loss: A Prospective Simulation Study. *Scientific Reports*. 2017;7:46333.
- [35] Legendre G, Richard M, Brun S, Chancerel M, Matuszewski S, Sentilhes L. Evaluation by obstetric care providers of simulated postpartum blood loss using a collector bag: a French prospective study. *The Journal of Maternal-Fetal & Neonatal Medicine*. 2016;29(21):3575-81.
- [36] Tixier H, Boucard C, Ferdynus C, Douvier S, Sagot P. Interest of using an underbuttocks drape with collection pouch for early diagnosis of postpartum hemorrhage. *Archives of gynecology and obstetrics*. 2011;283(1):25-9.
- [37] Cortet M, Deneux-Tharaux C, Dupont C, Colin C, Rudigoz R-C, Bouvier-Colle M-H, et al. Association between fibrinogen level and severity of postpartum haemorrhage: secondary analysis of a prospective trial. *British journal of anaesthesia*. 2012;108(6):984-9.
- [38] Collins PW, Lilley G, Bruynseels D, Laurent DB-S, Cannings-John R, Precious E, et al. Fibrin-based clot formation as an early and rapid biomarker for progression of postpartum hemorrhage: a prospective study. *Blood*. 2014;124(11):1727-36.
- [39] De Lloyd L, Bovington R, Kaye A, Collis R, Rayment R, Sanders J, et al. Standard haemostatic tests following major obstetric haemorrhage. *International journal of obstetric anesthesia*. 2011;20(2):135-41.
- [40] Indrayan A. Clinical Agreement in Quantitative Measurements. In: Doi SAR, Williams GM, editors. *Methods of Clinical Epidemiology*. Berlin, Heidelberg: Springer Berlin Heidelberg; 2013. p. 17-27.
- [41] Shields LE, Smalarz K, Reffigee L, Mugg S, Burdumy TJ, Propst M. Comprehensive maternal hemorrhage protocols improve patient safety and reduce utilization of blood products. *American journal of obstetrics and gynecology*. 2011;205(4):368. e1-. e8.
- [42] Zhang W-H, Deneux-Tharaux C, Brocklehurst P, Juszczak E, Joslin M, Alexander S. Effect of a collector bag for measurement of postpartum blood loss after vaginal delivery: cluster randomised trial in 13 European countries. *BMJ*. 2010;340:c293.